MEMs Parallel Plate Rheometer for Oscillatory Shear Micro Rheology Measurements

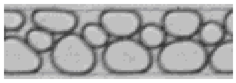
Gordon Christopher[1], Nicholas Dagalakis[2], Steven Hudson[1], and Kalman Migler[1]

[1]*Complex Fluids Group, Polymers Division, NIST, Gaithersburg, MD 20899*

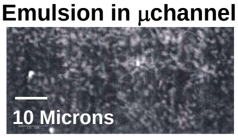
[2]*Intelligent Systems Division, NIST, Gaithersburg, MD 20899*

Motivation

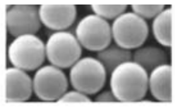
- Novel viscoelastic materials
  - Micro scale structure
- Confinement deforms structure
  - Alters rheology
- Characterization difficult
  - Small sample volumes
- Particle micro rheology does not probe entire micro structure
- Thin film measurements only elastic modulus



Emulsion in μchannel

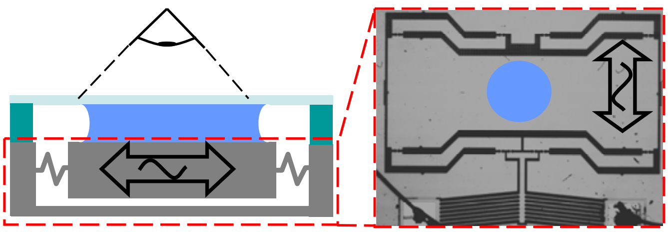


Agarose shear gel



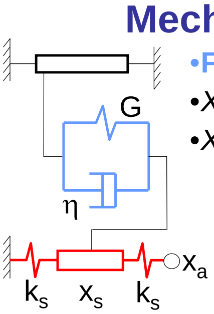
Colloidal Suspension

MEMs Parallel Plate Rheometer



- 1 mm² **nano-positioner** applies sinusoidal strain
  - Thermal Actuator
  - 0.1%< γ <25%
- O(1) um gap set with **thin film**
- Strain applied to the entire fluid body
- Optical observation
- Storage and loss moduli at 0.5 Hz< *f* <500 Hz
- Uses less than **10 nL of fluid**

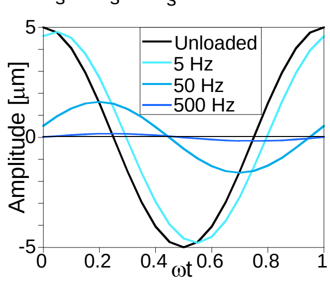
Mechanical Modeling



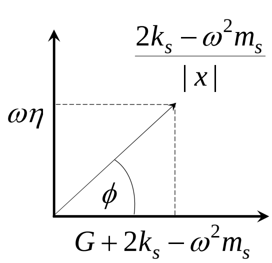
- **Fluid** modeled as Voigt Element
- X_s **nano-positioner** motion
- X_a actuator motion

$$\frac{m_s}{k_s}\ddot{x}_s + \frac{\eta}{k_s}\dot{x}_s + \left(2+\frac{G}{k_s}\right)x_s = x_a$$

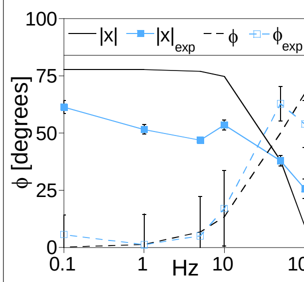
$$\frac{x_{s,loaded}}{|x_{s,unloaded}|} = |x|\sin(\omega t+\phi)$$



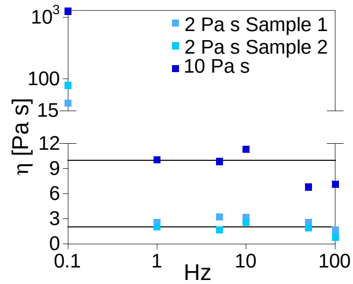
10 Pa's Oil



Viscous Fluid Calibration



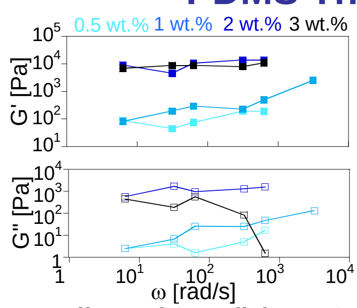
2 Pa's Oil



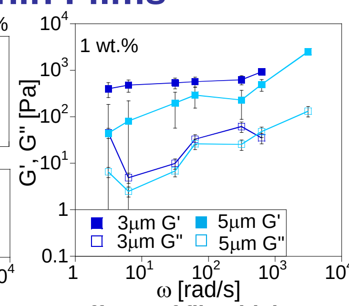
Viscosity Calibration

- Surface tension affects amplitude
- Model predicts general behavior
- ±25% device error on viscosity above 1 Hz
- ±150 Pa error on elastic modulus above 1 Hz

PDMS Thin Films

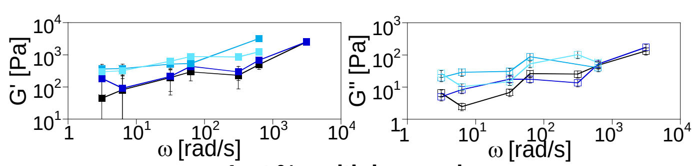


Effects of Crosslinker wt.%



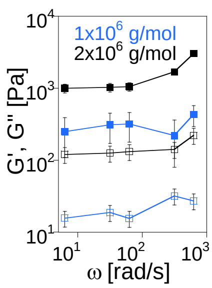
Effects of film thickness

- Moduli grow with increasing wt.%
- 3 wt.% G' consistent with DMA
- G' larger for thinner film
  Chen *et al., J. Micromech. Microeng.* (2009)
- Trends consistent with observed behavior
  Chang *et al., J. Polym. Sci. B* (2005)



1 wt.% multiple samples

Conclusions



5um Gap, High MW PIB in 500 g/mol PIB oligomer

- MEMs Rheometer with optical analysis can extract rheology
- Model matches observed phenomenon
- Consistent results for viscous fluids and viscoelastic thin films
- Large frequency domain,~3 decades, with O(1) um gap sizes
- Redesign of device should improve accuracy and sensitivity

National Institute of Standards and Technology

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